(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
3 May 2001 (03.05.2001)

PCT

(10) International Publication Number
WO 01/31766 A1

(51) International Patent Classification⁷: H02K 21/14

(21) International Application Number: PCT/NZ00/00209

(22) International Filing Date: 25 October 2000 (25.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
500679 26 October 1999 (26.10.1999) NZ
501077 12 November 1999 (12.11.1999) NZ

(71) Applicant *(for all designated States except US)*: **FISHER & PAYKEL LIMITED** [NZ/NZ]; 78 Springs Road, East Tamaki, Auckland (NZ).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **GIANNI, Christian, John, Wade** [NZ/NZ]; 78 Springs Road, East Tamaki, Auckland (NZ). **BOYD, John, H., Jr.** [US/US]; 57 Forest Hills Drive, Holland, MI 40424 (US).

(74) Agents: CALHOUN, Douglas, C. et al.; A J Park, Huddart Parker Building, 1 Post Office Square, Wellington (NZ).

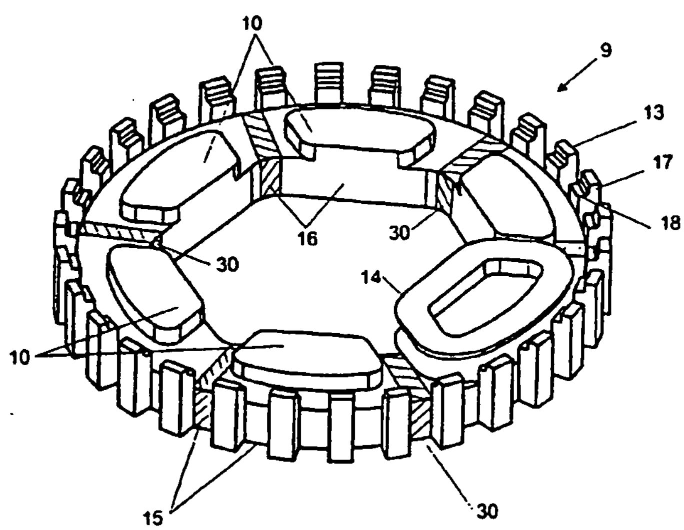
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: POLYPHASE TRANSVERSE FLUX MOTOR



(57) Abstract: A transverse flux motor having multiple stator phase windings which are electronically commutated to produce a rotating flux to drive a permanent magnet rotor (2) located externally of the stator (7). The stator (7) is formed by two complementary facing pieces (8, 9) each carrying half the stator poles (12, 13), the latter preferably being of claw pole configuration. The stator windings (11) are sandwiched between the stator pieces (8, 9) and wound about cores (10) which magnetically couple the stator pieces. Preferably the number of motor phases (P) is selected from the series 2,3, ..., N, the number of windings per phase (W) is selected from the series 1,2, ..., M, the number of poles per winding (PW) is selected from the series 2, 4, ..., L, and the number of stator poles (SP) is equal to the product P*WP*PW and the number of rotor poles is SP + or - W.

WO 01/31766 A1

POLYPHASE TRANSVERSE FLUX MOTOR

TECHNICAL FIELD

This invention relates to polyphase transverse flux dc motors and in particular, but not solely, motors of the "inside out" type where the rotor rotates externally of the stator.

PRIOR ART

The use of term "polyphase" in relation to a dc motor means a motor with a plurality of windings, or a plurality of sets of windings, which when excited sequentially from a dc source to produce a rotating flux. Commutation of the motor phases is normally achieved using electronic switching devices in a bridge arrangement with the switching sequences controlled by a micro-processor.

The advantages of transverse flux machines are well known. A transverse flux machine is capable of producing power densities several times greater than conventional electrical machines. This arises from the geometry of transverse flux motors which enables a larger number of poles while maintaining the same magnetomagnetic force (MMF) per pole as would be achieved in a conventional machine design.

Transverse flux machines have in the past been difficult to implement because standard core lamination techniques do not easily permit the three dimensional magnetic flux flow required in transverse flux machines. This difficulty is being overcome by the use of sintered powdered iron cores. These may be formed by a compression moulding technique.

Most transverse flux machine configurations disclosed hitherto are single phase machines. An example is disclosed in US patent 5,773,910 (Lange). Proposals for polyphase machines usually involve complex geometries which lead to difficulties in manufacture. For example US patents 5,117,142 (Von Zueygbergk), 5,633,551 (Weh) and 5,854,521 (Nolle).

It is therefore an object of the present invention to provide a polyphase transverse flux DC motor which is simple to manufacture.

DISCLOSURE OF THE INVENTION

Accordingly in one aspect the invention consists in a polyphase transverse flux dc motor comprising:

a rotor having alternating magnetic pole polarities at the periphery; and

a stator mounted co-axially with said rotor so as to provide at least one air gap there between, said stator including:

a first stator piece having a plurality of circumferentially disposed and spaced apart claw poles projecting in an axial direction,

a second stator piece complementary to said first stator piece and mounted co-axially in facing relationship with said first stator piece such that there is an axial spacing there between and oriented about the common axis such that the claw poles of the second pole piece circumferentially alternate with the claw poles of the first pole piece;

a plurality of magnetically permeable bridging cores disposed about the stator axis proximate to said claw poles and located between said first and second stator pieces to provide magnetic flux paths there between,

at least one said stator piece being provided with regions of magnetic high reluctance between the sites of said bridging cores, and

stator windings disposed about each bridging core each of which when supplied with an exciting current produce flux flow through those stator claw poles in the first and second pole pieces which are proximate to the corresponding bridging core thereby producing flux in said air gap adjacent such claw poles, each winding or a selected set of windings constituting the windings for one of a plurality of motor phases which in use are electronically commutated to produce a flux in said air gap which rotates about the stator axis.

In a further aspect the invention consists in a polyphase transverse flux dc motor comprising:

a rotor having a plurality of permanent magnets circumferentially disposed and separated by magnetically permeable material to provide alternating magnetic pole polarities at the periphery, said magnets being magnetised in the circumferential direction; and

a stator mounted co-axially with said rotor so as to provide at least one air gap therebetween, said stator including:

a first stator piece having a plurality of circumferentially disposed and spaced apart claw poles projecting in an axial direction,

a second stator piece complementary to said first stator piece and mounted co-axially in facing relationship with said first stator piece such that there is an axial spacing therebetween and oriented about the common axis such that the claw poles of the second pole piece circumferentially alternate with the claw poles of the first pole piece,

a plurality of magnetically permeable bridging cores disposed about the stator axis proximate to said claw poles and located between said first and second stator pieces to provide magnetic flux paths therebetween,

at least one said stator piece being provided with regions of magnetic high reluctance between the sites of said bridging cores, and

stator windings disposed about each bridging core each of which when supplied with an exciting current produce flux flow through those stator claw poles in the first and second pole pieces which are proximate to the corresponding bridging core thereby producing flux in said at least one air gap adjacent to such claw poles, each winding or a selected set of windings constituting the windings for one of a plurality of motor phases which in use are electronically commutated to produce a flux in said air gap which rotates about the stator axis.

In a further aspect the invention consists in a method of making a stator for a polyphase transverse flux dc motor, comprising the steps of:

forming a first stator piece having a plurality of circumferentially disposed and spaced apart claw poles projecting in an axial direction,

forming a second stator piece similar and complementary to said first stator piece, providing a plurality of magnetically permeable bridging cores to be symmetrically disposed about the stator axis proximate to said claw poles between said first and second stator pieces to provide magnetic flux paths therebetween,

providing regions of high magnetic reluctance between the sites of said bridging cores in either or both of the first or second stator pieces,

placing stator windings about each bridging core,

assembling the first and second stator pieces co-axially in facing relationship with each other and spaced axially apart by said bridging cores with said second stator piece oriented about the common axis such that the claw poles of said second pole piece circumferentially alternate with the claw poles of said first pole piece;

each said winding or a selected set of said windings constituting the windings for one of a plurality of motor phases such that in use when supplied with an exciting current produce flux flow through those stator claw poles in the first and second pole pieces which are proximate to the corresponding bridging core.

In yet a further aspect the invention consists in a rotor having a plurality of circumferentially disposed permanent magnets separated by segments of high permeability material to form rotor poles,

a stator mounted co-axially with said rotor so as to provide at least one air gap therebetween, said stator having a plurality of circumferentially disposed and spaced apart poles,

at least one stator winding per phase disposed such that when supplied with an exciting current produce flux flow through stator poles which are proximate thereto to produce a flux in said air gap adjacent to said poles, said windings in use being electronically commutated to produce a flux in said air gap which rotates about the stator axis,

the improvement defined by the relationship wherein the number of motor phases (P) is selected from the series 2, 3, ...,N, the number of windings per phase (W) is selected from the series 1, 2 ...M, the number of poles associated with each winding (PW) is selected from the series 2, 4, ...1, and the number of stator poles (SP) is equal to the product P*WP*PW and the number of rotor poles is SP±W.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 shows a diagrammatic diametrical cross-section through a motor according to the present invention,

Figure 2 shows an exploded view of a stator for the motor in Figure 1 with Figure 2A showing a first stator piece, Figure 2B showing a second complementary stator piece and Figure 2C showing four of six stator windings,

Figure 3 shows a partial pictorial view of the periphery of the stator indicating a representative flux path produced by a single winding,

Figure 4 shows a stator piece to which an electronics circuit board is mounted,

Figure 5 shows a fragmentary view of the magnetic components of one preferred form of rotor and the flux flow therethrough,

Figure 6 shows an alternative rotor configuration,

Figure 7 shows diagrammatically a three phase commutation circuit for the motor,

Figure 8 shows one piece of a two piece mould for forming a stator piece of the motor, and

Figure 9 is a partial view of a stator piece showing a further pole configuration.

BEST MODES FOR CARRYING OUT THE INVENTION

In one preferred form of the invention the rotor 2 is located externally of the stator 7 as indicated in Figure 1. As is mentioned later a variety of known rotor configurations may be used. Rotor 2 as shown comprises an annular ring of axially oriented magnetic material pieces 3A interspersed with similarly configured permanent magnets 3B (not shown in Figure 1). The permanent magnets 3B are magnetised in the

circumferential direction with successive magnets being magnetised with opposite polarities. The annular ring of magnetic components is supported by a cylindrical non-magnetic backing wall 4, preferably formed from a plastics material integrally with a base 5 and hub which carries the rotor shaft 6. The shaft is supported by bearings mounted either conventionally in a housing supporting the stator or within the appliance which the motor is to power. An example of the latter type of mounting in a clothes washing machine is disclosed in US patent 5,150,589.

An alternative rotor configuration is shown in Figure 6. In this construction the rotor 200 comprises an annular ring of magnetisable and magnetically permeable material, rotating exteriorly of the stator. In one embodiment of this configuration a number of circumferentially orientated magnets 202 are disposed around the internal periphery of the rotor. The permanent magnets 202 are magnetised in the radial direction, alternating in polarity, and abut an annular soft magnetic material return path 204 to complete the magnetic circuit. The annular ring of magnetic components is supported by a cylindrical backing wall 206, preferably formed from a plastics material integrally with a base 208 and hub which carries the rotor shaft.

The motor stator 7 (see also Figure 2) is fabricated by two complementary facing pieces 8 and 9 formed from material of high magnetic permeability spaced axially apart by bridging cores 10, also formed of a highly permeable material. Each stator piece 8 and 9 includes a number of spaced apart and axially directed poles 12 and 13 respectively, located at the periphery. The stator poles are of the claw pole type.

The bridging cores 10, of which there are six in the embodiment shown, are symmetrically disposed about the axis of the stator and located in proximity to the stator poles. The purpose of these cores is to allow magnetic flux to flow from one stator piece to the other. Each bridging core also conveniently forms the core for a corresponding stator winding 11.

The stator illustrated is a three "phase", 60 pole stator with two windings per phase. The two primary stator pieces 8 and 9 are, in the embodiment illustrated, similar in form and are assembled together face to face with their respective axially directed poles 12 and 13 facing the opposing stator piece with the relative rotational orientation of each stator piece being such as to allow the poles 12 of the upper piece to locate within the interspacing of the poles 13 of the lower piece. In the preferred form the interpole spacing exceeds the width of each pole and the axial length of each pole is extended such that the oppositely directed poles of the two stator pieces overlap. This can be seen in Figure 3.

Each stator piece can be visualised as a circular plate 15 carrying at its periphery spaced apart claw poles 12 and 13 respectively. A cavity 16 is provided centrally in each plate to conserve material and to allow the passage of the rotor shaft. Each pole is oriented axially and in the preferred embodiment has a circumferential width less than the interpole spacing. Each pole stands proud of "plate" 15 and the pole tips are rebated to form a reduced area tip 17 which has the effect of reducing leakage flux between adjacent pole tips and/or the other stator piece. Other pole configurations can be adopted to minimise flux leakage. For example, the claw poles can be tapered in one or more ways. In Figure 8 a pole is shown tapered in two directions. First the side faces 211 and 212 may taper from the root of the pole to its outer radial face. Second inner face 213 may taper from where it joins the stator piece "plate' 15 to the tip 17. Further, in the stepped pole embodiment shown in Figure 2 the step may be a ramped rebate instead of assuming the right angled rebate form shown.

To ensure at least the bulk of the flux produced by each winding flows through the poles proximate to that winding and not through the plate material to other windings it is necessary to provide regions of high reluctance in at least one of the plates 15 between the bridging cores. Magnetically these regions appear as "slots" and in the preferred embodiment suitable slots 30 are provided in the lower stator piece plate as shown in Figure 2B. In theory the slots 30 could be air gaps but to retain the unitary structure of each stator piece an engineering strength low permeability material is used. Preferably this is moulded into the stator piece and also forms the stator hub as shown in Figure 8.

The stator must be formed in two pieces to allow the several internal windings to be put in place during manufacture. The two pieces must be magnetically linked to provide flux paths between the two and the bridging cores adopted to achieve this are formed by providing on the inner face of one or both stator plate 15 raised "islands" 10 which on assembly of the two pieces abut with their opposite number on the facing piece to provide a magnetic core about which a winding may be placed. The bridging cores may be formed integrally with one of the stator pieces. Alternatively some bridging cores can be formed integrally with one piece while the others are formed integrally with the second piece. As a further alternative "half height" bridging cores may be formed in each stator piece which during assembly of the stator are physically brought together in series to complete the magnetic circuit. This alternative construction is that shown in Figure 2. In this embodiment the stator pieces are similar but not identical since the bridging cores 10 must align while at the same time allowing for misalignment of the poles of the respective pieces. In yet a further alternative the

bridging cores may be formed separately and located with the plates 15 during assembly.

This stator geometry allows a single winding to produce flux through several poles. Each winding is separately wound on single bobbins 14 (see Figure 2C) according to conventional winding techniques. The bobbins 14 are preferably formed from a plastics material and are shaped so as to fit about each bridging core 10.

In the three phase stator described two diametrically opposite windings are connected together in parallel or in series and on commutation are excited in series with the windings of another phase to clause flux to flow in the stator in the vicinity of the excited windings. One flux path so produced is shown in Figures 3 and 5. Each winding in this embodiment causes flux to flow through five poles in each stator piece. For the path shown the flux passes through the bridging cores 10 (flux segment a) into the plate of the upper stator piece (flux segment b), then into a pole of the upper piece (segment c), leaves the pole and crosses the motor air gap (segment d) radially into the physically most proximate soft magnetic material piece 3A of rotor 2 (shown in Figure 5), passes circumferentially into and through adjacent permanent magnet 3B and into the magnetic material piece 3A on the opposite side of this magnet (segment e, visible in Figure 5), passes through the soft magnetic material piece in an axial direction and leaves the soft magnetic material piece to cross the air gap radially (segment f) to the closest pole on the lower stator piece, travels through that pole (segment g) to the lower stator plate where it proceeds radially (segment h) to return to the bridging core 10 to complete the flux circuit.

In the case of the alternative rotor construction shown in Figure 6 the flux path through the rotor differs somewhat. The flux leaves the pole and crosses the motor air gap (segment d, Figure 3) radially into the physically most proximate permanent magnet (202, Figure 6) circumferentially through the soft magnetic material return path (204, Figure 6) and back radially through an adjacent permanent magnet to cross the air gap radially (segment f, Figure 3) to the closest pole on the lower stator piece.

Only one flux path for two poles is shown for purposes of clarity. In reality flux flows three dimensionally through all five poles in the upper stator piece and all five poles of the lower stator piece which are excited by winding 11.

In a two phase firing embodiment (refer to Fig 7), after commutation of motor current through the windings of phase A and phase B, motor current is then commutated to flow through the phase A and phase C windings to cause the radially directed flux produced at the periphery of the stator to move around the periphery of the stator in the desired direction. The permanent magnets in rotor 2 which are

alternately located between the soft magnetic material pieces 3A are attracted or repelled by the stator flux to cause the rotor to move in synchronism with the rotating stator flux. The supply of the winding current and the commutation of the windings can be carried out in a known manner using two semi-conductor switching devices per phase ("totem pole") in a bridge configuration between dc rails with the devices being switched under the control of a micro-processor (not shown) which stores sequences of switching patterns which are caused to execute in a cyclical manner to produce a flux which rotates about the stator in one direction or other as selected. Such stator winding commutation control is described in US patents 4,540,921 (Boyd), 4,857,814 (Duncan) and WO 98/35429 (Boyd et al), particularly with reference to figures 1 (which corresponds to present Figure 7) and 2 of the latter.

The present invention provides a polyphase transverse flux dc motor having simple geometry which is relatively easy to fabricate. As opposed to some prior art proposals the stator geometry allows for a motor having a single air gap.

In a motor according to the present invention the following relationship holds:-

If the number of phases P = 2, 3, ..., N;

the number of windings per phase W = 1, 2, ..., M;

and the number of poles per winding PW = 2, 4, ..., L;

then the number of stator poles SP is given by SP = P x W x PW; and

the number of rotor poles RP = SP±W per phase.

It is advantageous to make the number of windings per phase even to balance the radial forces acting when the phase is excited and in some cases it is desirable for the number of poles per winding to be even when an opposed pair claw pole geometry is chosen. However, it is possible to have an odd number of poles per winding, for example 9.

When the number of windings per phase is two or more the windings may connected in either series or in parallel. However a parallel connection may have the advantage in that it will reduce the radial force dissymmetry in the presence of air gap dissymmetries.

In the embodiment illustrated and described three phases have been chosen with two windings per phase and 10 poles per winding. This results in a stator having 60 poles and the rotor to use with the stator must have either 62 or 58 poles.

It is convenient for manufacturing purposes to locate the motor commutation electronics in physical association with the motor. This is shown in Figure 4 where the electronics are located on a printed circuit board 20 which is fixed to stator piece 8.

The stator pieces can be formed by pressing a soft magnetic material powder, such as iron powder, into a mould 40 shaped for the purpose (see Figure 8). For one of the two stator pieces a former 41 made of low permeability material is preferably used to provide the high reluctance slots 30 in the stator pieces. The former remains as an integral part of the stator piece on removal of the piece from the mould. This former can also function as a bearing retainer. Pressing the soft magnetic material powder around the former allows very accurate concentricity between the bearing and the air gap. In the preferred embodiment the other stator piece does not require slots and no former is required.

WE CLAIM:

1. A polyphase transverse flux dc motor comprising:

a rotor having a plurality of permanent magnets circumferentially disposed and separated by magnetically permeable material to provide alternating magnetic pole polarities at the periphery, said magnets being magnetised in the circumferential direction; and

a stator mounted co-axially with said rotor so as to provide at least one air gap therebetween, said stator including:

a first stator piece having a plurality of circumferentially disposed and spaced apart claw poles projecting in an axial direction,

a second stator piece complementary to said first stator piece and mounted co-axially in facing relationship with said first stator piece such that there is an axial spacing therebetween and oriented about the common axis such that the claw poles of the second pole piece circumferentially alternate with the claw poles of the first pole piece,

a plurality of magnetically permeable bridging cores disposed about the stator axis proximate to said claw poles and located between said first and second stator pieces to provide magnetic flux paths therebetween,

at least one said stator piece being provided with regions of magnetic high reluctance between the sites of said bridging cores, and

stator windings disposed about each bridging core each of which when supplied with an exciting current produce flux flow through those stator claw poles in the first and second pole pieces which are proximate to the corresponding bridging core thereby producing flux in said at least one air gap adjacent to such claw poles, each winding or a selected set of windings constituting the windings for one of a plurality of motor phases which in use are electronically commutated to produce a flux in said air gap which rotates about the stator axis.

2. A polyphase transverse flux dc motor comprising:

a rotor having alternating magnetic pole polarities at the periphery; and

a stator mounted co-axially with said rotor so as to provide at least one air gap therebetween, said stator including:

a first stator piece having a plurality of circumferentially disposed and spaced apart claw poles projecting in an axial direction,

a second stator piece complementary to said first stator piece and mounted co-axially in facing relationship with said first stator piece such that there is an axial spacing therebetween and oriented about the common axis such that the claw poles of the second pole piece circumferentially alternate with the claw poles of the first pole piece,

a plurality of magnetically permeable bridging cores disposed about the stator axis proximate to said claw poles and located between said first and second stator pieces to provide magnetic flux paths therebetween,

at least one said stator piece being provided with regions of magnetic high reluctance between the sites of said bridging cores, and

stator windings disposed about each bridging core each of which when supplied with an exciting current produce flux flow through those stator claw poles in the first and second pole pieces which are proximate to the corresponding bridging core thereby producing flux in said air gap adjacent to such claw poles, each winding or a selected set of windings constituting the windings for one of a plurality of motor phases which in use are electronically commutated to produce a flux in said at least one air gap which rotates about the stator axis.

3. A polyphase transverse flux dc motor according to claim 2 wherein said rotor comprises a plurality of permanent magnets circumferentially disposed around a magnetically permeable return path, said magnets being magnetised in the radial direction.

4. A polyphase transverse flux dc motor according to claims 1 or 2 wherein said bridging cores are integrally formed as part of one stator piece.

5. A polyphase transverse flux dc motor according to claim 1 or 2 wherein some bridging cores are integrally formed as part of one stator piece while the balance are formed as part of the other stator piece.

6. A polyphase transverse flux dc motor according to claim 1 or 2 wherein complementary halves of each bridging core are integrally formed as part of each stator piece.

7. A polyphase transverse flux dc motor according to any one of claims 1 to 6 wherein the spacing interval between claw poles exceeds the width of each claw pole.

8. A polyphase transverse flux dc motor according to claim 7 wherein the end portion of each claw pole of a respective stator piece extends axially into the interclaw space of the opposite stator piece.

9. A polyphase transverse flux dc motor according to any one of the preceding claims wherein the number of motor phases (P) is selected from the series 2, 3, ...,N, the number of windings per phase (W) is selected from the series 1, 2, ...M, the number of poles associated with each winding (PW) is selected from the series 2, 4, ...l, and the number of stator poles (SP) is equal to the product P*WP*PW and the number of rotor poles is SP±W.

10. A method of making a stator for a polyphase transverse flux dc motor, comprising the steps of:

forming a first stator piece having a plurality of circumferentially disposed and spaced apart claw poles projecting in an axial direction,

forming a second stator piece similar and complementary to said first stator piece, providing a plurality of magnetically permeable bridging cores disposed about the stator axis proximate to said claw poles between said first and second stator pieces to provide magnetic flux paths therebetween,

providing regions of high magnetic reluctance between the sites of said bridging cores in either or both of the first or second stator pieces,

placing stator windings about each bridging core,

assembling the first and second stator pieces co-axially in facing relationship with each other and spaced axially apart by said bridging cores with said second stator piece oriented about the common axis such that the claw poles of said second pole piece circumferentially alternate with the claw poles of said first pole piece;

each said winding or a selected set of said windings constituting the windings for one of a plurality of motor phases such that in use when supplied with an exciting current produce flux flow through those stator claw poles in the first and second pole pieces which are proximate to the corresponding bridging core.

11. In a polyphase transverse flux dc motor including:

a rotor having a plurality of circumferentially disposed permanent magnets separated by segments of high permeability material to form rotor poles,

a stator mounted co-axially with said rotor so as to provide an air gap therebetween, said stator having a plurality of circumferentially disposed and spaced apart poles,

at least one stator winding per phase disposed such that when supplied with an exciting current produce flux flow through stator poles which are proximate thereto to produce a flux in said air gap adjacent to said poles, said windings in use being electronically commutated to produce a flux in said air gap which rotates about the stator axis,

the improvement defined by the relationship wherein the number of motor phases (P) is selected from the series 2, 3, ...,N, the number of windings per phase (W) is selected from the series 1, 2 ...M, the number of poles associated with each winding (PW) is selected from the series 2, 4, ...1, and the number of stator poles (SP) is equal to the product P*WP*PW and the number of rotor poles is SP±W.

12. A polyphase transverse flux dc motor substantially as hereinbefore described with reference to the accompanying drawings.

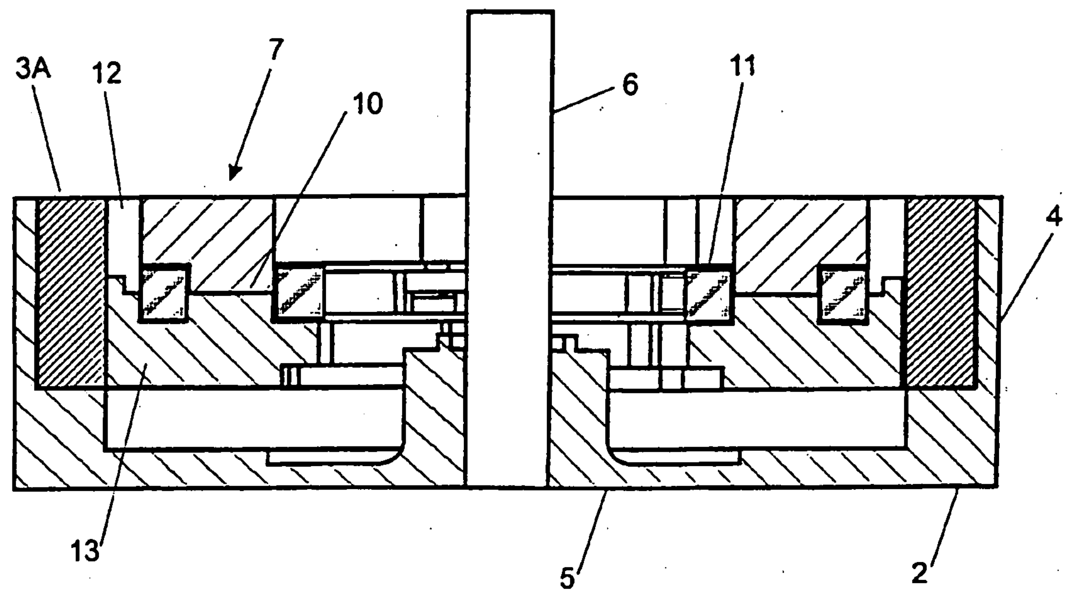


FIG. 1

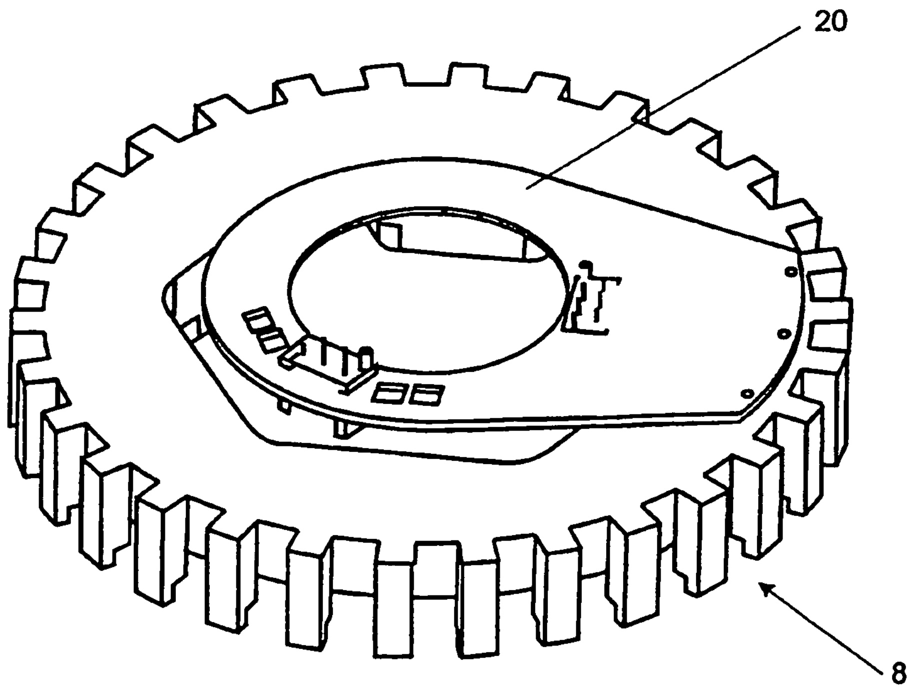


FIG. 4

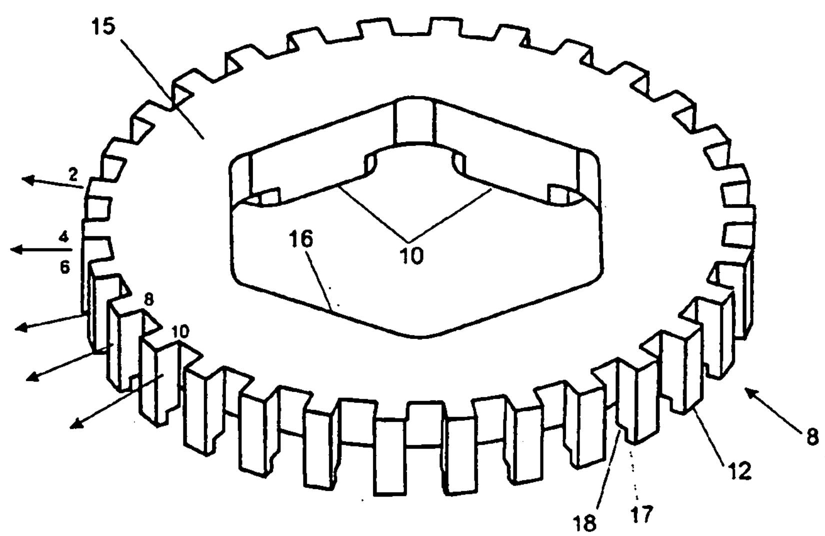


FIG. 2A

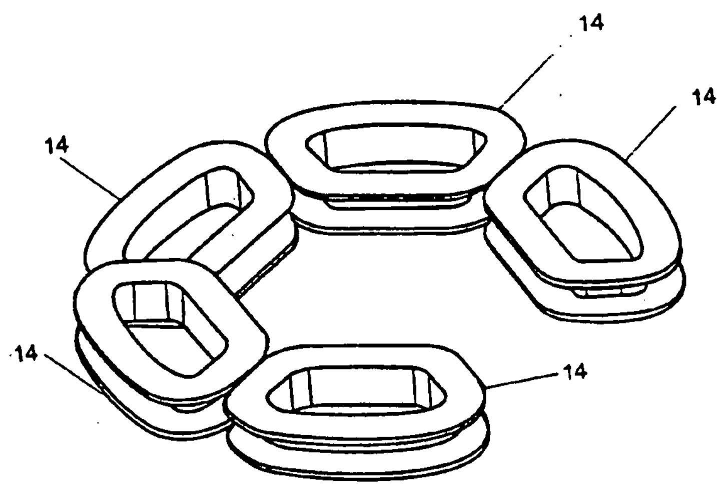


FIG. 2C

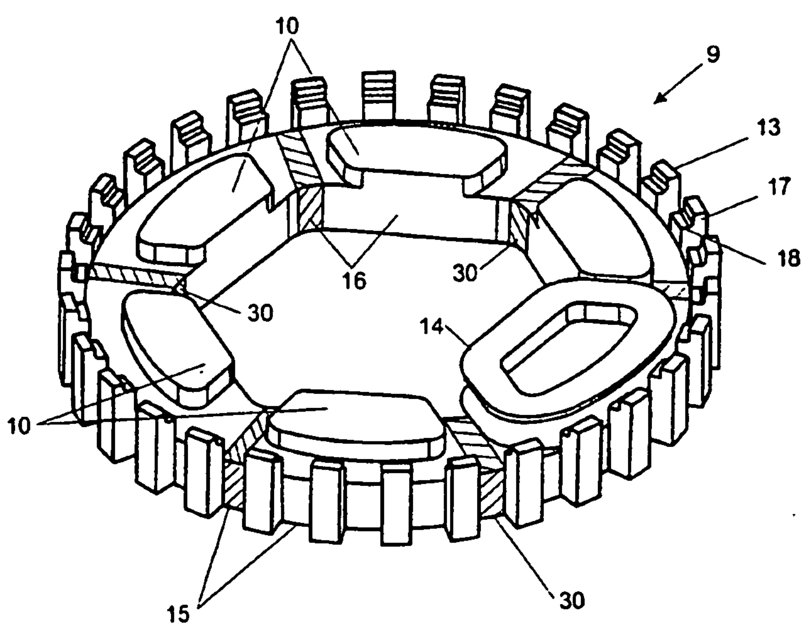


FIG. 2B

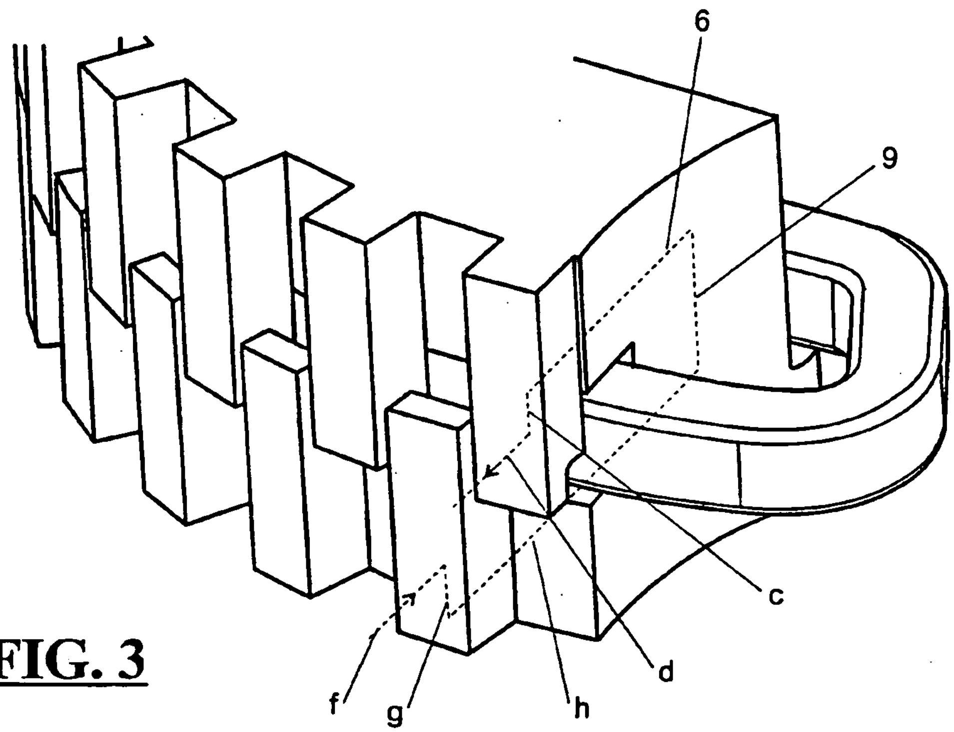
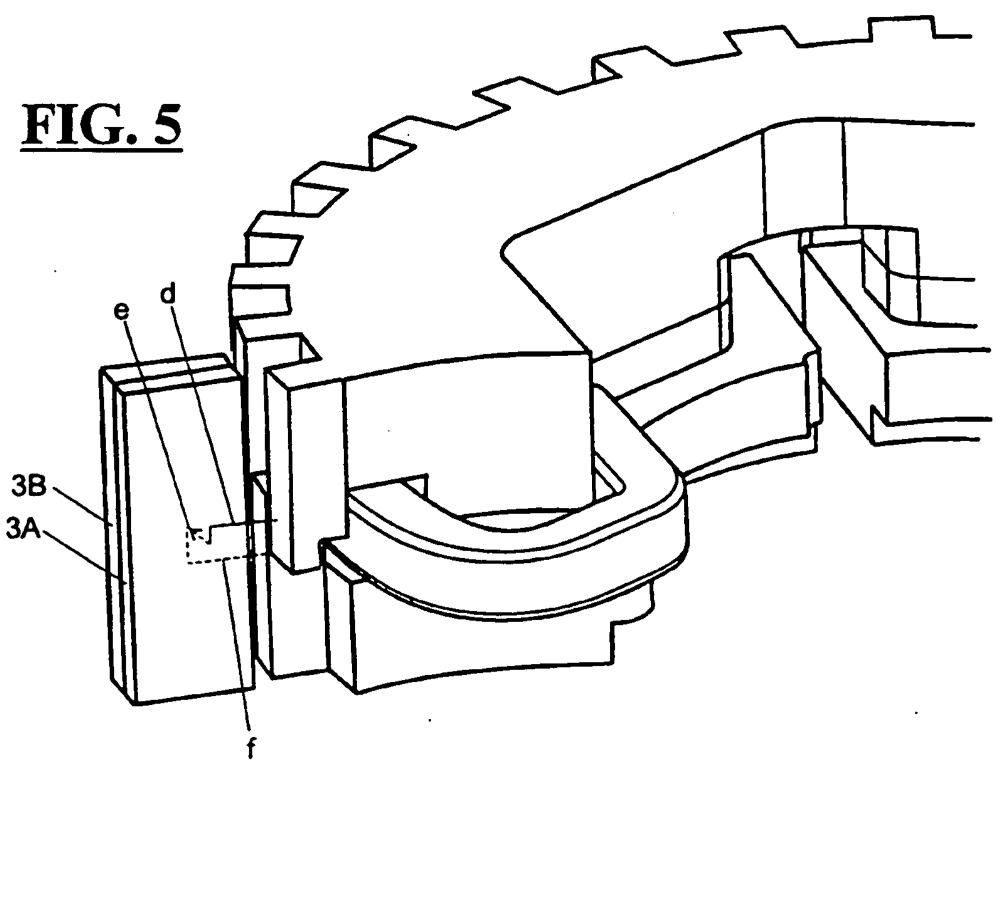


FIG. 3

FIG. 5



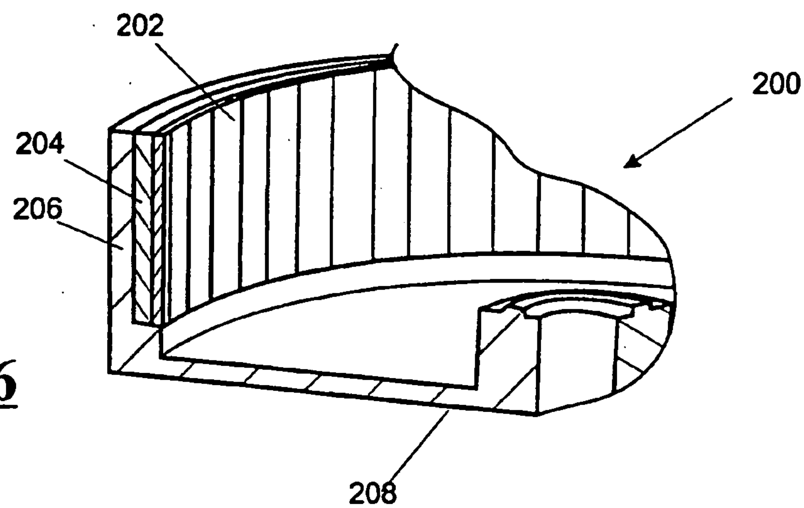


FIG. 6

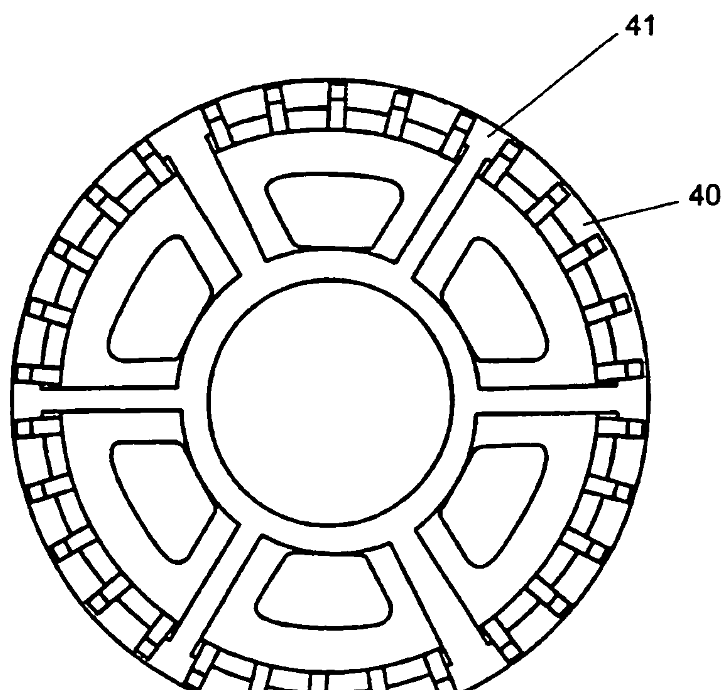


FIG. 8

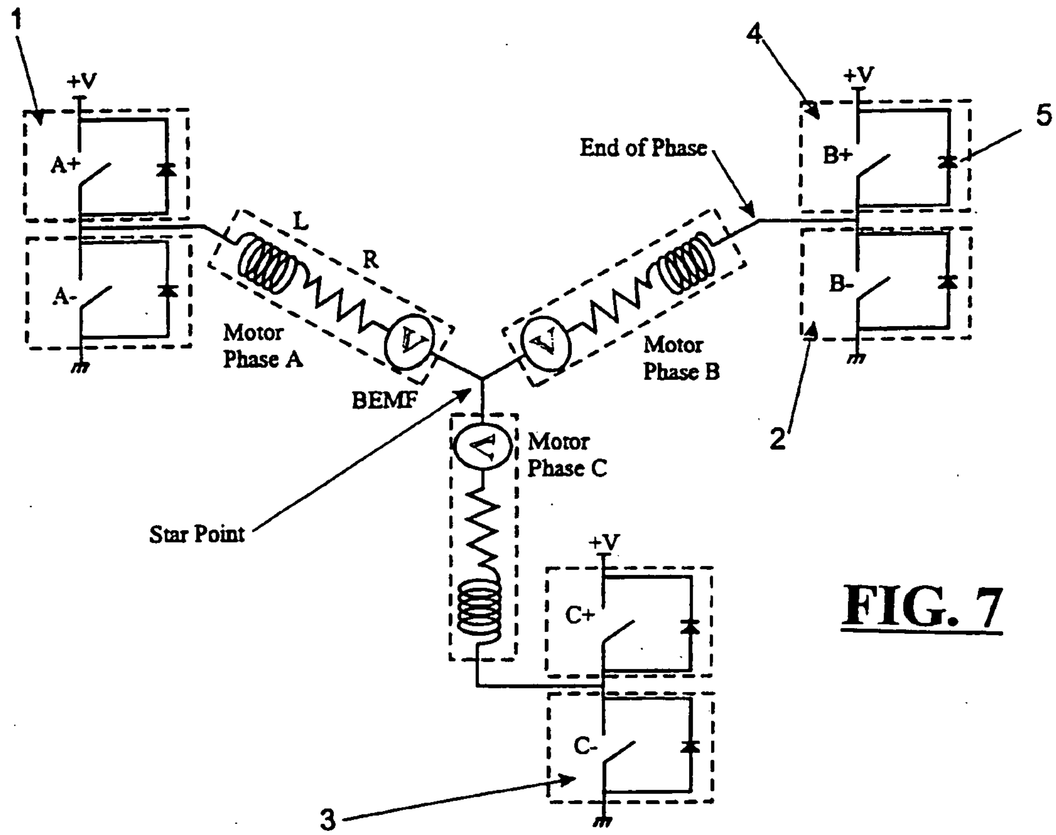

1
+V
A+
A-
L
R
Motor
Phase A
BEMF
4
+V
5
B+
End of Phase
B-
Motor
Phase B
2
Motor
Phase C
Star Point
+V
C+
C-
3

FIG. 7

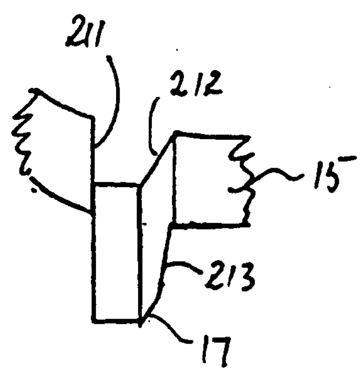

211
212
15
213
17

FIG. 9

INTERNATIONAL SEARCH REPORT	International application No. PCT/NZ00/00209

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: H02K 21/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC : H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPAT : H02K with (motor, polyphase, multiphase, cross flux, transverse flux)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4883999 A (HENDERSHOT) 28 November 1989 See entire document	
A	EP 858149 A (VOITH TURBO GMBH & CO. KG) 12 August 1998 See abstract	

☐ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 10 January 2001	Date of mailing of the international search report 15 January 2001
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer A. ALI Telephone No : (02) 6283 2607

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ00/00209

Box I **Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos :

   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos :

   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos :

   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II **Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

See attached sheet for details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box
(To be used when the space in any of Boxes I to VIII is not sufficient)

Continuation of Box No: II

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Claims 1-10. It is considered that "a second stator piece complementary to the first stator piece and mounted coaxially in facing relationship with said first stator piece such that there is an axial spacing there-between and oriented about the common axis such that the claw poles of the second pole piece circumferentially alternate with the claw poles of the first stator piece" comprises a first "special technical feature".

2. Claims 11. It is considered that "the improvement defined by the relationship of the number of motor phases, the number of windings per phase, the number of poles associated with each winding, the number of stator poles and the number of rotor poles" comprises a second "special technical feature".

Since the above-mentioned groups of claims do not share any of the technical features identified, a "technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept, a priori.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/NZ00/00209**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Member			
US 4883999	CA 1300215	EP 395747	WO 9001823	US 4995159
	US 5015903	EP 465462	WO 9011641	
EP 858149	CA 2228629	DE 19704392	JP 10217709	
				END OF ANNEX